Removable Encapsulants

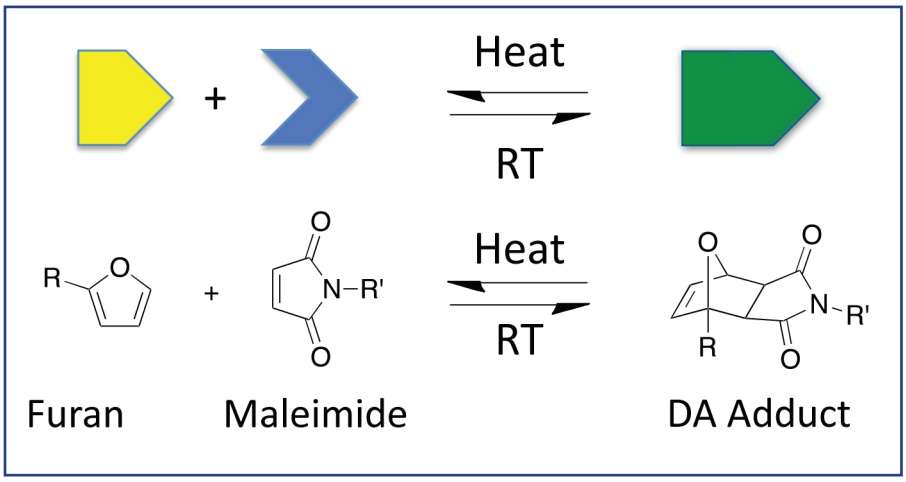

Figure 1: Reversible Diels Alder reaction (RT= room temperature)

Engineers are now able to access critical engineered system assemblies without risk of damage

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Encapsulant foam materials have been used for decades in electromechanical assemblies for shock and vibration mitigation, structural support, and high voltage containment. In order to rework or repair the delicate assemblies, engineers have to gingerly remove the pervasive encapsulants without causing component damage. Current methods of traditional encapsulant foam removal involve the use of mechanical picking with tools, chemical removal with aggressive solvents, or media blasting, all which are known to damage or destroy printed wiring boards, plastics, and wiring interconnects. Easy encapsulant removal without damage to components is thus highly desirable and will become even more critical for engineering assemblies that must be in service for a long lifetime. To meet this need, Sandia has developed a suite of thermally-removable encapsulant foams.

The easily removable encapsulants are based on the well-known Diels-Alder (DA) chemical reaction (Figure 1). One variant of the DA reaction is the thermally-reversible [4 + 2] cyclo-addition between furan and maleimide molecules. Simply mixing the two species together at room temperature will cause the reactants to form a DA adduct. Heating the adduct to temperatures greater than 50 °C, in the presence of a solvent, will induce the retro-DA reaction, which reverts the DA adduct back to the furan and maleimide starting materials. Under the correct conditions, the process is completely reversible and can occur over and over again without degradation to the starting materials.

Sandia has implemented these thermally-removable encapsulants into engineered systems in four different products: 1) REF308 removable epoxy foam, 2) REF320 removable epoxy foam, 3) RSF200 removable syntactic foam, and 4) RCC removable conformal coating. Each of the encapsulants utilizes a bis-epoxy DA resin that can undergo standard amine-epoxy curing reactions. Under normal operating conditions, the cured removable materials behave like typical encapsulants. They can be removed by placing the entire assembly in a stirred bath of furfuryl alcohol, a solvent derived from corn cobs, at a temperature of 50 °C. Under the conditions of elevated temperature and solvent, the reversion of the DA adducts back to their starting materials causes the encapsulants to covalently disassemble, dissolve, and be

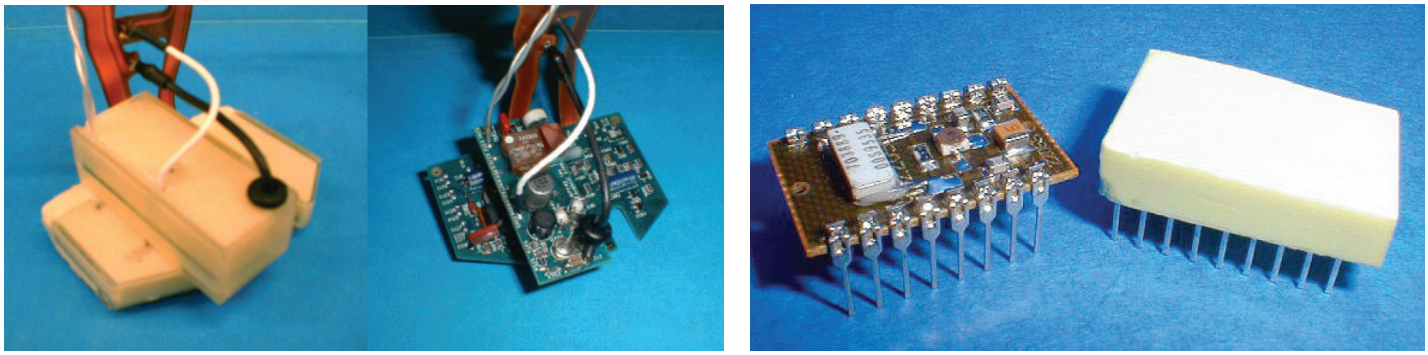

Figure 2: Foam and encapsulant removal: (left) removable epoxy foam (REF), (right) removable syntactic foam (RSF).

removed from the assembly (Figure 2). Furfuryl alcohol at 50 °C has been shown to be relatively harmless to mechanical and electrical components.

The removal mechanism incorporated into the materials by the addition of DA adducts provides a novel capability to perform repair, replacement, and surveillance of engineered systems that had not been available with conventional polymeric encapsulants. In particular, the ability to perform surveillance on encapsulated systems that require a long service lifetime is extremely valuable in assessing aging and reliability of high-value electromechanical systems. Through this work, Sandia has spawned new areas of research and has developed several other products using thermally-reversible DA reactions. These include thermally-reversible, covalent, self-assembling dendrimers, polymeric macromolecules, and cleavable surfactants (References).

References

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